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MATCHING NETWORK FOR RF PLASMA SOURCE

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Background of the Invention

Field of the Invention

The invention relates generally to plasma generators, and more particularly to matching networks for RF driven plasma generators which may be used as ion or electron sources.

Description of the Prior Art

Multicusp plasma generators are used in ion (or electron) sources. While the plasma may be generated by a dc filament discharge, an inductively driven plasma generator using an RF antenna in the plasma production chamber is cleaner.

A matching network is needed for operating a plasma generator with an RF power supply. This is to eliminate the reflected power at the power supply/antenna interface so that the maximum power output from the supply is delivered into the plasma generator. The matching network is connected between the external RF power supply and the RF antenna inside the plasma production chamber.

U.S. Patent 5,587,226 shows a plasma ion source with a general representation of a matching network coupling the RF supply to the RF antenna. No specific circuit design and structure are shown.

Matching networks are normally large in size and cannot be incorporated into a compact Focused Ion Beam (FIB) system such as described in U.S. Patent 5,945,677. Thus a design is needed which meets the size requirement for a compact FIB tool.

Summary of the Invention

Accordingly it is an object of the invention to provide a compact matching network for coupling an RF power supply to an RF antenna in a plasma generator.

The invention is a simple and compact impedance matching network for matching the plasma load to the impedance of a coaxial transmission line and the output impedance of an RF amplifier at radio frequencies. The matching network is formed of a resonantly tuned circuit formed of a variable capacitor and an inductor in a series resonance configuration, and a ferrite core transformer coupled to the resonantly tuned circuit. This matching network is compact enough to fit in existing compact focused ion beam systems.

Brief description of the Drawings

Fig. 1 is a schematic circuit diagram of the RF matching network of the invention.

Figs. 2A, B are top and side views of a compact RF matching network of the invention.

Detailed Description of the Invention

As shown in Fig. 1, RF matching network 10 is formed of a resonantly tunable circuit 12 connected to a ferrite core transformer T. Tunable circuit 12 is formed of a variable capacitor C and an inductor L in a series resonance configuration. A portion 14 of tunable circuit 12 forms the secondary winding of transformer T, which is typically a single winding. Transformer T also has a multi-turn primary winding 16. Transformer T also has a core 18 which is made of a plurality of ferrite cores 18-i.

RF amplifier (RF power supply or source) 20 is connected through 50Ω coaxial cable 22 to the input of matching network 10, i.e. to one end of primary winding 16 whose opposite end is connected to ground. An RF antenna (inductive coil) 24 is connected to the output of matching network 10, i.e. to resonantly tuned circuit 12. RF antenna 24 is positioned inside a plasma generator 26 in which plasma is produced.

A plasma ion source is a plasma generator from which beams of ions can be extracted. Alternatively, an electron beam can be extracted from the plasma by changing the polarity of the extraction voltage. A multicusp plasma ion source has an arrangement of magnets that form magnetic cusp fields to contain the plasma. The plasma generating source is surrounded by columns of permanent magnets. The magnets are placed around the cylindrical side wall as well as an end flange. In most cases an extraction system is placed at an open end.

Multicusp plasma ion sources are illustrated by U.S. Patents 4,793,961; 4,447,732; 5,198,677; 6,094,012, which are herein incorporated by reference.

The transformer T serves two functions. First, it electrically isolates the ion source 26 from the RF amplifier 20, enabling the ion source 26 to float to a potential other than the RF source 20. Second, the turn ratio between the primary windings 16 and secondary winding 14, which typically ranges from 3:1 to 8:1, is selected to transform the

plasma impedance to 50Ω. The circuit 12 is tuned to resonance by adjusting the capacitance C; resonance is indicated by a minimum in the reflected power.

An illustrative specific embodiment which was fabricated and tested uses 12 ferrite cores with a 1.25 inch OD and 0.75 inch ID, made of M-type ferrite. The material is chosen with sufficiently high magnetic permeability to contain the field, without significant losses, at the operating frequency, e.g. 2 MHz or 13.56 MHz. The capacitor C was a CACA-175-005 capacitor by Jennings Corp. which is rated at 5kV and has a capacity range of 5-125pF. The inductor L was made with silver plated copper tubing with approximately 10 turns, each with 1.25 inch OD. A silver plated copper short is provided to reduce the number of turns on the inductor without rewinding it.

The entire structure, as shown in Figs. 2A, B, fits within a cylindrical volume 6 inches in diameter and 8 inches long. Adjustable capacitor (C) 30, inductor or choke (L) 32, and transformer (T) 34 are electrically connected and mounted in a cavity 36. The components 30, 32, 34 are electrically connected to the antenna through electrical feedthroughs 38 which pass through base 40. Similarly, there is an electrical connection (not shown) from the primary winding of transformer 34 to the RF amplifier.

Another attractive feature of this system is that it shields much of the RF radiation from escaping into the environment, thereby reducing possible noise on external electronics.

A number of technical problems were overcome to produce the invention. The challenge was to fit a matching network capable of operating with at least 200 W of continuous wave RF power into the existing depression on commercial FIB systems. Design issues included the heating of the ferrite cores and capacitor, and the maximum operating voltage of the capacitor. The system should be matched to run an oxygen

plasma at appropriate power levels, e.g. greater than 200 W. Another concern was maintaining adequate distance from the surrounding structure to prevent arcing due to RF voltages.

This technology could be used on any system that uses a plasma source in which the plasma is generated with RF radiation. The specific application for which the matching network was designed is for a focused ion beam system. However, there is presently interest in using a plasma source as a source of electrons. This matching network would work for such a system as well.

Changes and modifications in the specifically described embodiments can be carried out without departing from the scope of the invention which is intended to be limited only by the scope of the appended claims.